The Development of High Performance Actuator Material with Low Lead Content using the Spark-plasma-sintering Method

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INTRODUCTION

Origin of colossal effects (e.g. colossal magnetoresistance in magnanites, colossal proximity effect in underdoped high temperature superconductors, giant dielectric constant in Pb-containing relaxor ferroelectrics):

intrinsic inhomogeneities

J. Burgy, M Mayr, V. Martin-Mayor, and E. Dagotto, Phys. Rev. Lett. 87, 277202(2001).

In $(Na_{0.5}K_{0.5})NbO_3$, the competing ferroelectric and antiferroelectric interactions coexist. By modifying its disorder with $PbTiO_3$, what will happen? Could the giant or colossal effect be possible?

Objectives of the present research

- To characterize dielectric and piezoelectric properties of $(Na_{0.5}K_{0.5})NbO_3$-$PbTiO_3$ ceramics.
- To investigate the effect of random fields on performance of perovskite piezoelectrics.

EXPERIMENTAL

Sample preparation

mixing — Na_2CO_3, K_2CO_3, PbO, TiO_2, Nb_5O_2

↓

calcination — 950^{o}C X 2hr, twice

↓

SPS sintering — 1020 ~ 1100^{o}C X 5 min, ~ 60 MPa, vacuum

↓

post annealing — 950^{o}C X 5 hr, air

Measurements

- X-ray diffraction
- Scanning Electronic Microscopy
- Dielectric constant
- *DE*-loop
- Electromechanical coupling coefficient

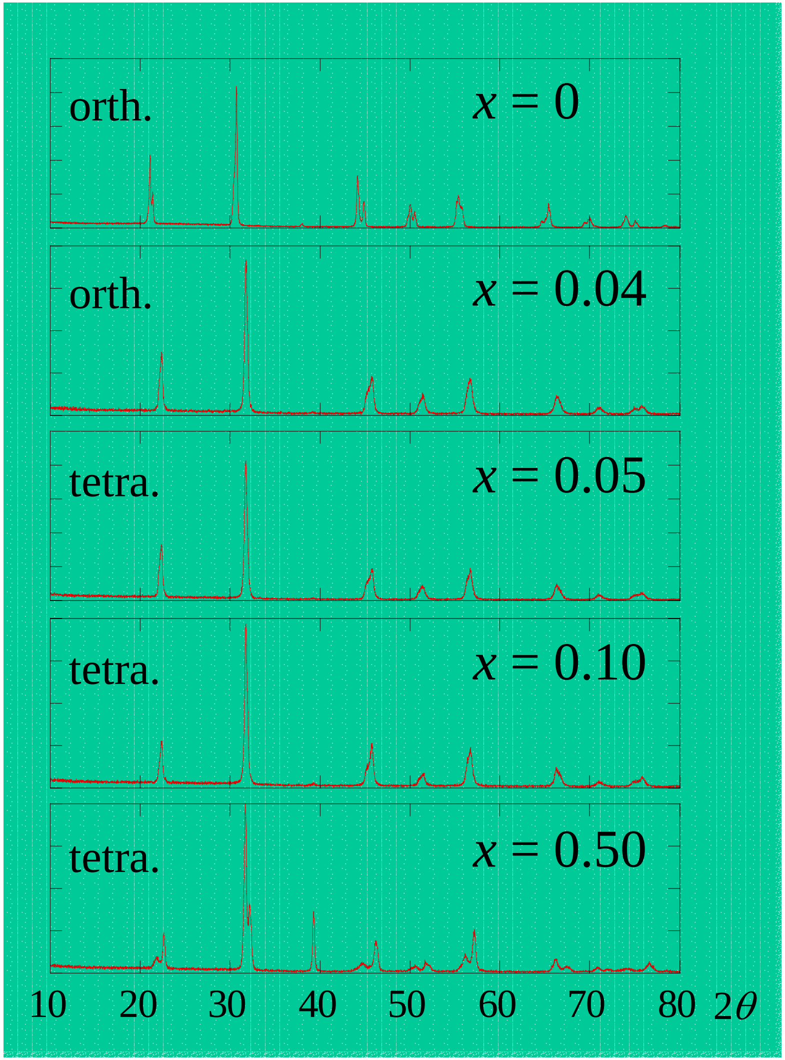
resonance method,

Sample sizes: ~5mmx5mmx0.5mm

poling conditions:

E ~30 kV/cmx15 mins, RT

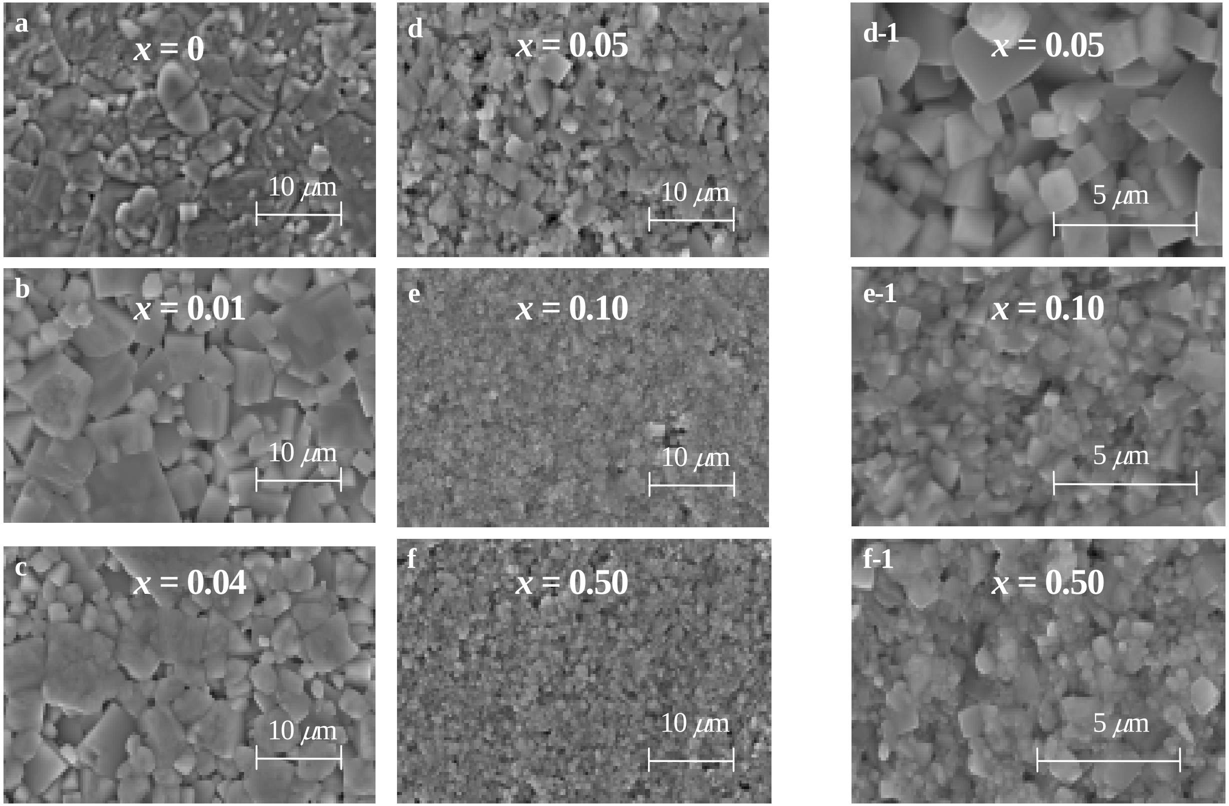
RESULTS



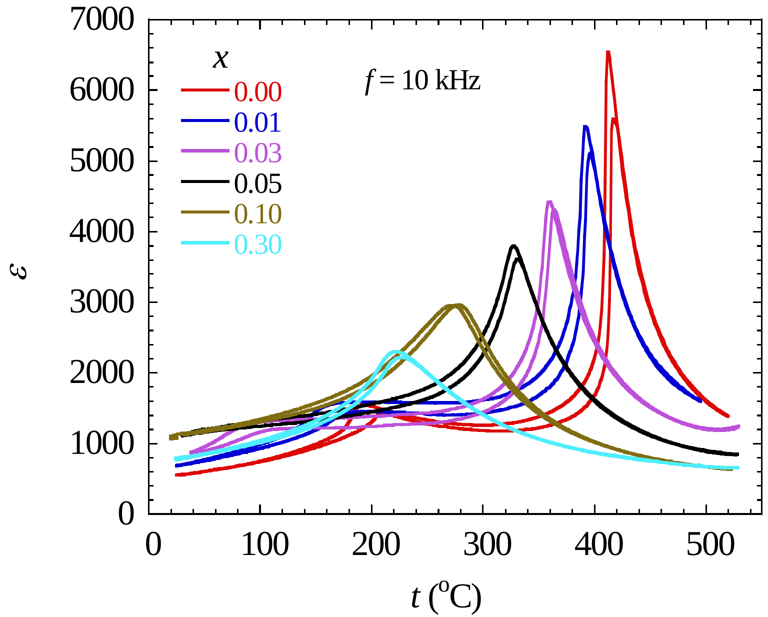
orth.
x = 0
orth.
x = 0.04
tetra.
x = 0.05
tetra.
x = 0.10
tetra.
x = 0.50
10
20
30
40
50
60
70
80
2θ

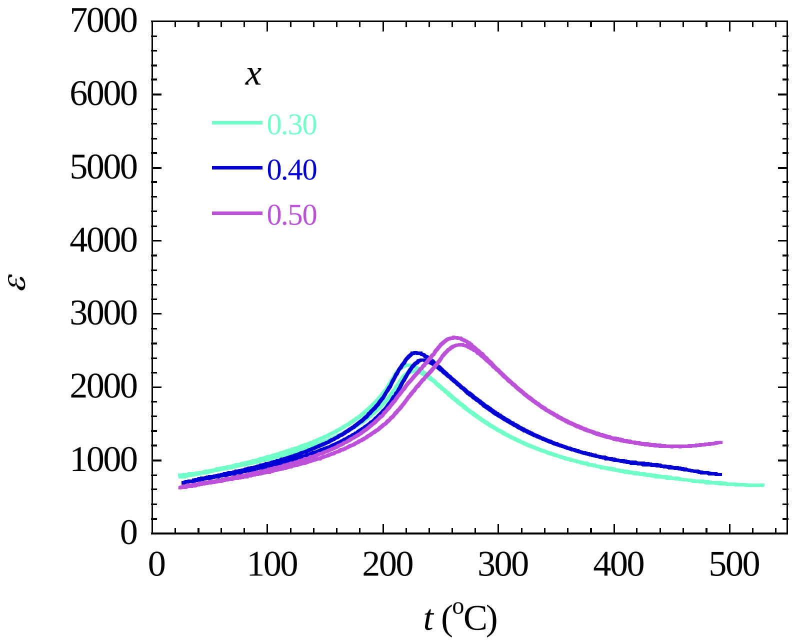
SEM images

X 3000 X 10000

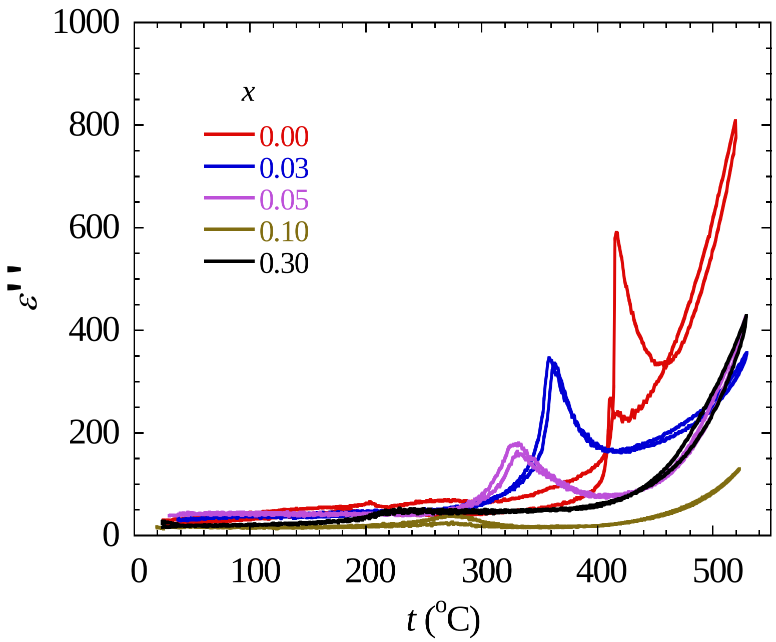


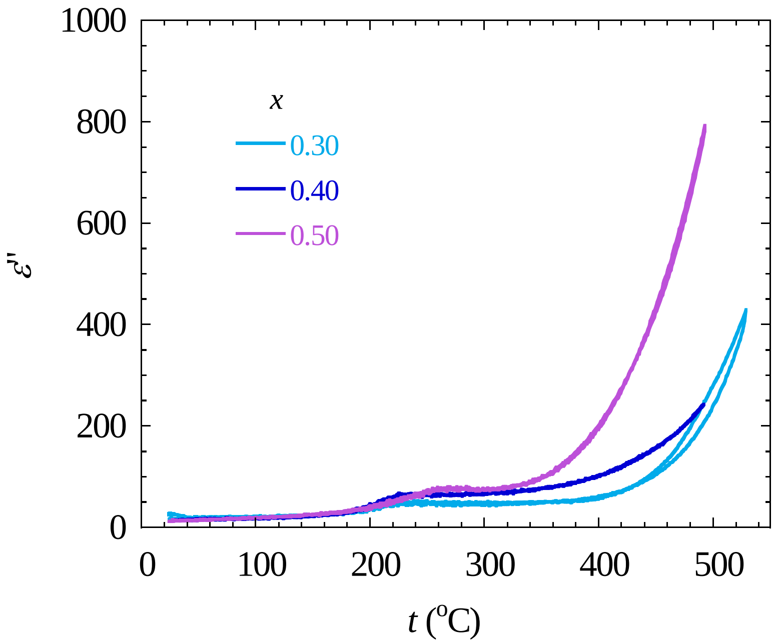
Real part of the dielectric constant



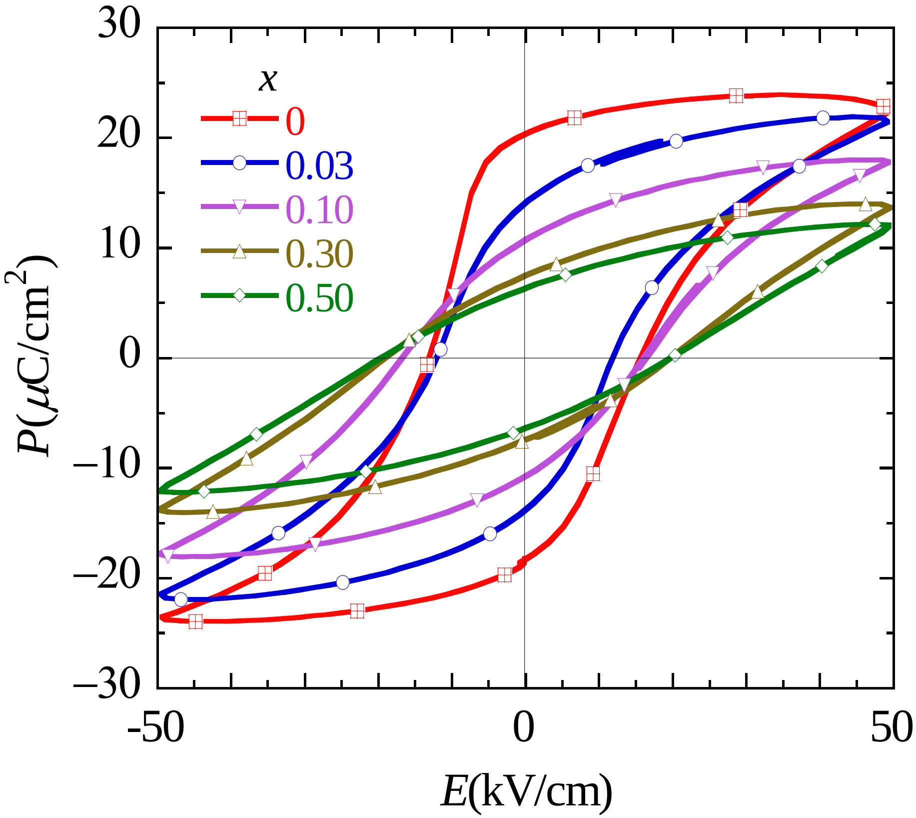


Imaginary part of the dielectric constant

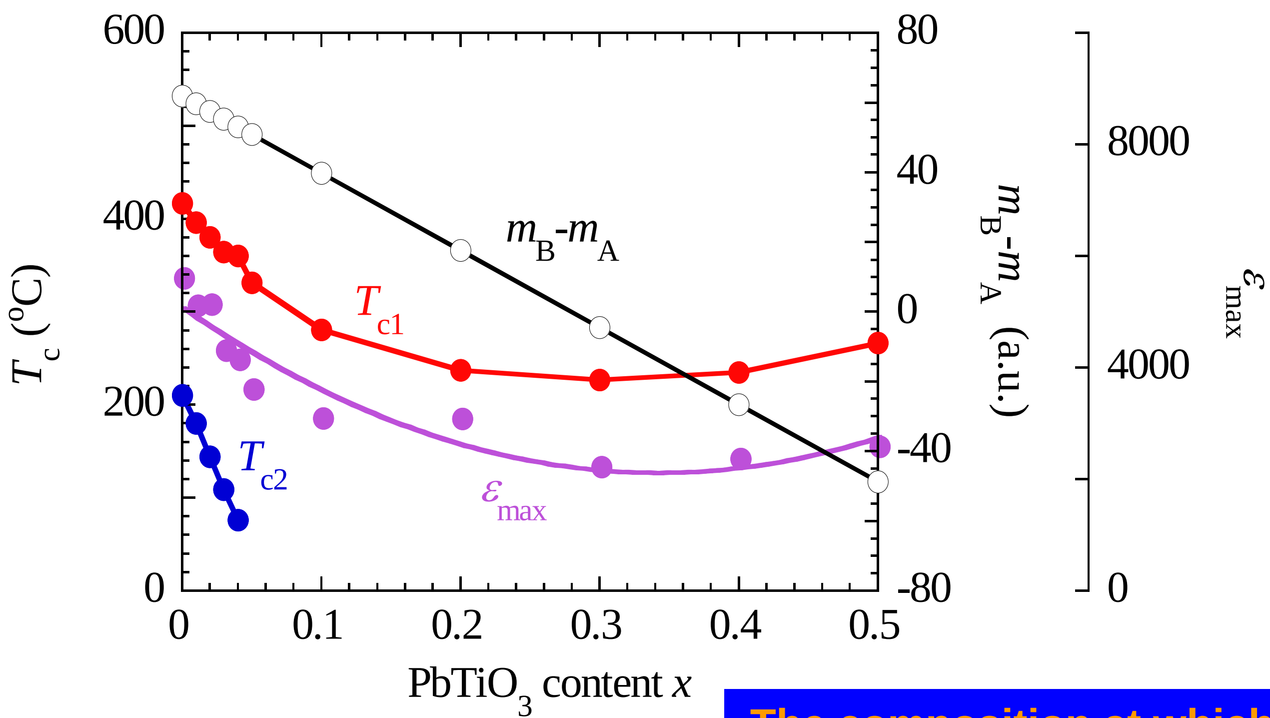




D vs. *E* loops



T_c, ε_{max}, and m_B-m_A *vs. x*



The composition at which m_B-m_A = 0 (x = 0.28) is very close to the composition where T_{c1} and ε_{max} show minimum (x = 0.30).

List of piezoelectric properties

$PbTiO_3$ content y	0	0.01	0.02	0.03	0.04	0.05	0.10	0.20	0.30	0.40	0.50
Relative density (%)	96.0	99.8	97.2	98.2	95.9	96.0	98.3	93.1	98.2	96.5	97.1
Remnant polarization (μC/cm^2)	19	21	19	14	15	15	11	11	8	8	6
Coercive field (kV/cm)	14	16	19	12	15	15	17	21	19	26	20
k_p (%)	18	26	21	25	22	24	16	12	13	10	10

SUMMARIES

- High density of (1-x)($Na_{0.5}K_{0.5}$)NbO_3-$x$$PbTiO_3$ ($x \leq 0.50$) samples were prepared by the SPS method.
- The improved electric field induced strain has been observed in the low x range. The modified domain structure is considered to be mainly responsible for the improvement.
- The dielectric properties tend to degrade with the intensification of the random fields.

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